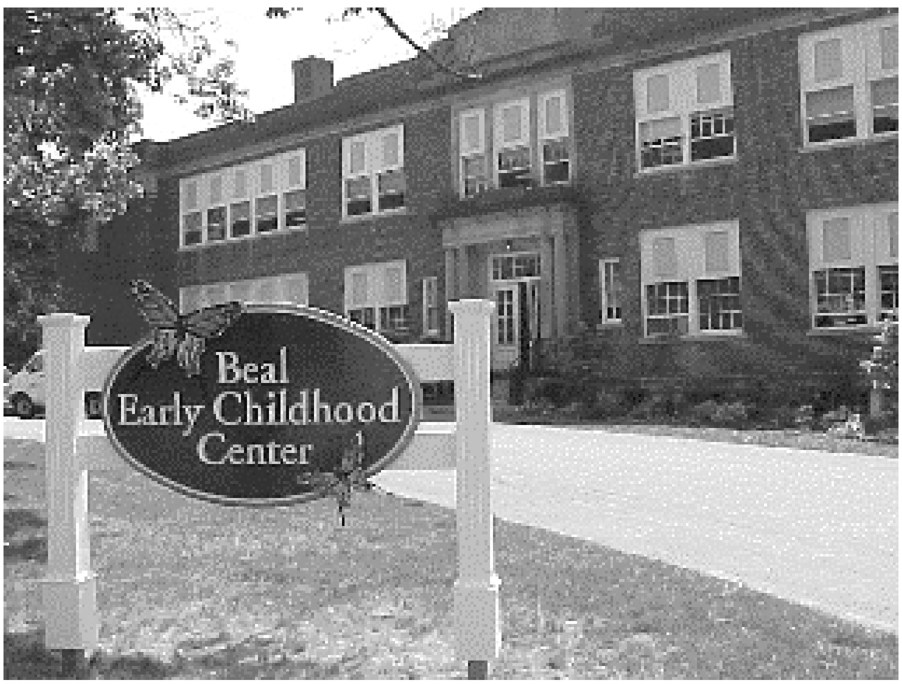
INDOOR AIR QUALITY ASSESSMENT

Beal School
1 Maple Avenue
Shrewsbury, MA 01545



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
August 2006

Background/Introduction

At the request of Nancy Allen, Director of the Shrewsbury Health Department (SHD), the Massachusetts Department of Public Health's (MDPH), Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at the Beal School, 1 Maple Avenue, Shrewsbury, Massachusetts. The request was prompted by general indoor air quality concerns, as well as reoccurring strep throat infections. On March 10, 2006, a visit to conduct an indoor air quality assessment was made by Sharon Lee, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. During the assessment, Ms. Lee was accompanied by Robert Moore, Health Agent, SHD and Jill Wensky, Nurse, Beal School. Robert A. Cox, Superintendent of Public Buildings for the Town of Shrewsbury was also present for portions of the assessment.

The Beal School is a two-story brick building constructed in 1922. The building contains general classrooms, a gymnasium, library, art rooms, music rooms, kitchen, cafeteria and administrative offices. In recent years, modifications have been made to the basement for the creation of additional space. In addition, a drop ceiling system was installed to prevent movement of fragmented plaster pieces and dust to occupied spaces. No major renovations have been made to the building.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were conducted with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. MDPH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The school houses a total student population of 450 kindergarten and first grade students, as well as approximately 40 staff members. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in 11 of 28 areas surveyed, indicating a lack of adequate air exchange some of the areas surveyed during the assessment. The school does not have a mechanical ventilation system to provide fresh air. It appears that ventilation was originally provided to classrooms by a natural gravity system via vents located on upper portions of walls (Picture 1). The system has since been abandoned. Heating elements within the ductwork would produce heat, which rises and creates airflow that draws air from classroom via the exhaust vents (Pictures 2 and 3); this process is known as "the stack effect". Under the current circumstances, it appears that the building does not have a functioning ventilation system. Without sufficient supply and exhaust ventilation, normally occurring environmental pollutants can build up and lead to air quality/comfort complaints. If not in use, consideration should be given to sealing all supply/exhaust vents to prevent backdrafting and movement of materials into occupied areas.

It appears that the only means for creating airflow in the building is the use of windows and cross-ventilation. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. This hinged window, known as a transom, enables classroom occupants to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through a classroom and subsequently pass through the open transom. Airflow then enters the hallway, passing through the opposing open classroom transom, into the opposing classroom and finally exits the building on the leeward side (opposite the windward side) (Figure 1). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. This system fails if the windows or transoms are closed (Figure 2). Rooms that are not opposite other classrooms would have difficulty in creating cross ventilation and would need some means to increase air movement (e.g., fan in an open window). Transoms appear to have been sealed as part of an energy conservation program. In order to create airflow, hallway doors need to be opened.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, consult Appendix A.

Temperature measurements ranged from 71^{o} F to 75^{o} F, which were within the MDPH recommended comfort range during the assessment. The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is often difficult to control temperature and maintain comfort without mechanical ventilation equipment.

The relative humidity measured in the building during the assessment ranged from 32 to 47 percent, which was within or close to the lower end of the MDPH recommended comfort range in most areas. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several potential pathways for moisture to enter the building were identified:

- Missing/damaged mortar and spaces in brick around the exterior of the building (Picture 4).
- Damage to the building foundation (i.e., fissures) (Picture 5).
- Spaces around wooden doorframes (Pictures 6 and 7).
- Damaged windows frames in a number of classrooms (Picture 8).

Breaches in the building exterior can allow water to penetrate the building. Repeated water penetration can result in chronic wetting of building materials, which can potentially lead to microbial growth. In addition, these breaches in the building envelope can provide a means of egress for pests/rodents into the building.

A number of drainage pits are located along the perimeter of the building. These pits are designed to drain water away from the building. Leaves, papers and other debris were observed on the floor of these pits (Picture 9). Such debris can prevent drainage and provide a source for mold growth and associated odors.

Several classrooms contained a number of plants (Picture 10). In one area, a plant was observed on a carpeted floor (Picture 11). Plants, soil and drip pans can serve as sources of mold growth, and thus should be properly maintained. Placement of plants on porous materials (i.e., carpet, paper products) should be avoided since these materials are sources for mold growth.

Spaces between the sink countertop and backsplash were noted in several classrooms (Picture 12/Table 1). Improper drainage or sink overflow can lead to water penetration to countertop wood, the cabinet interior and areas behind cabinets. Like other porous materials, if these materials become wet repeatedly they can provide a medium for mold growth.

An inactive insect nest was observed in a classroom (Picture 13). Nests can contain bacteria and may be a source of allergenic material. Nests should be placed in resealable bags to prevent aerosolization of allergenic material.

Lastly, a dehumidifier was observed in one classroom (Picture 14). Reservoirs of dehumidifiers are designed to catch water during operation. Reservoirs should be emptied and cleaned regularly to prevent microbial and/or bacterial growth.

Other IAQ Evaluations

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Indoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured outside the school were also ND.

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations the day of the assessment were measured at 76 $\mu g/m^3$, which exceeded the NAAQS PM2.5 level of 65 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 18 to 43 $\mu g/m^3$, which were below the NAAQS PM2.5 level. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner; and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Indoor TVOC measurements throughout the building were ND. Outdoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC-containing products. While no measurable TVOC levels were detected in the indoor environment, VOC-containing materials were noted. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Several other conditions that can affect indoor air quality were noted during the assessment. Occupants expressed concerns about the possible presence of rodents and health issues that can be associated with their wastes and dander. Rodents can be a source of disease and infestation can result in indoor air quality related symptoms due to materials in their wastes. Mouse urine and feces contain a protein that is a known sensitizer (US EPA, 1992). A sensitizer is a material that can produce symptoms (e.g., rhinitis and skin rashes) in sensitive individuals. A three-step approach is necessary to eliminate rodent infestation:

1. removal of the rodents;
2. cleaning of waste products from the interior of the building; and
3. reduction/elimination of pathways/food sources that are attracting rodents such as toasters/toaster ovens in classrooms.

Although no evidence of rodents was observed during the assessment, materials that can attract rodents were observed. In one classroom area, sugar sprinkles were observed in and around the sand table area (Picture 15). If food is used in projects, materials and the immediate area should be thoroughly cleaned..

As previously discussed, drop ceiling tile systems were installed to prevent movement of dust and materials from the original plaster ceiling. In some classrooms, the ceiling tile system divides the exhaust vents (Picture 16). These unsealed exhaust vents facilitate the movement of materials from areas above the drop ceiling system into occupant areas. In addition, many of the panels to the abandoned ductwork were removed and are no longer intact (Pictures 17 and 18). If no longer in use, the ductwork should be sealed completely to prevent movement of materials, odors and/or pests within the building.

Open utility holes and breaches in walls were observed in a number of areas (Picture 19). Missing and ajar ceiling tiles were also observed. Open utility holes and missing/ajar ceiling tiles can provide a pathway for the movement of drafts, odors and particulate matter.

In some classrooms, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Some classrooms contained portable air purifiers (Picture 20). This equipment is normally equipped with filters that should be cleaned or changed as per manufacturer's instructions to avoid the build up and re-aerosolization of dirt, dust and particulate matter. In addition, air purifiers should be placed within the breathing zone rather than at floor level.

Conclusions/Recommendations

As discussed, the assessment was prompted in part by reoccurring strep throat infections. Given the age of the students and the number of items that are shared amongst the student population, consideration should be given to cleaning shared toys and other common equipment on a weekly basis or when soiled, with an appropriate antimicrobial solution followed by soap and water (CDC,1996). This is particularly important given the lack of mechanical ventilation. In view of the findings at the time of the assessment, the following recommendations are made:

1. Use openable windows to increase air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
2. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
3. Seal abandoned ductwork and vents to prevent movement of dusts, odors and/or other materials into occupied areas.
4. Repair window frames where necessary to prevent water/pest intrusion or drafts.

5. Seal utility holes/breaches in exterior walls and install weather stripping around exterior doors to prevent water penetration, drafts and pest entry. Re-point brickwork where necessary.

6. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.

7. Use the principles of integrated pest management (IPM) to rid the building of pests. Activities that can be used to eliminate pest infestation may include the following:

   - Do not use recycled food containers. Seal recycled containers in a tight fitting lid to prevent rodent access.
   - Remove non-food items that rodents are consuming.
   - Stored foods in tight fitting containers.
   - Avoid eating at workstations. In areas were food is consumed, periodic vacuuming to remove crumbs are recommended.
   - Regularly clean crumbs and other food residues from toasters, toaster ovens, microwave ovens coffee pots and other food preparation equipment. Consider relocating this equipment from classrooms to break room/kitchen areas.
   - Examine each room and the exterior walls of the building for means of rodent egress and seal appropriately. Holes as small as ¼" is enough space for rodents to enter an area. If doors do not seal at the bottom, install a weather strip as a barrier to rodents.
   - Reduce harborages (e.g., cardboard boxes) where rodent may reside.

   A copy of the IPM Guide can be obtained at the following Internet address: http://massnrc.org/ipm/docs/ipmkitforbuildingmanagers.pdf

8. Remove leaves and debris from subterranean pits seasonally; ensure proper drainage.
9. Seal breaches between sink countertops and backsplashes to prevent damage. Replace damaged materials where necessary.
10. Place nests and similar allergen containing materials in resealable clear bags or clear boxes to prevent exposure to allergenic materials.
11. Clean and maintain dehumidifiers as per the manufacture's instructions.
12. Consider developing a written notification system for building occupants to report indoor air quality issues/problems, if one is not already in place (Appendix B). Ensure concerns are relayed to the maintenance department/ building management in a manner to allow for a timely remediation of the problem.
13. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.
14. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://mass.gov/dph/indoor_air

References

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials and Code Administrators International, Inc., Country Club Hill, IL. Section M-308.1.1.

CDC. 1996. ABCs of Safe and Healthy Child care: A Handbook for Child Care Providers. Washington, DC: Department of Health and Human Services.

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

US EPA. 1992. Indoor Biological Pollutants. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, research Triangle Park, NC. EPA 600/8-91/202 January 1992.

US EPA. 2000a. National Ambient Air Quality Standards (NAAQS). . US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

US EPA. 2000b. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/tools4s2.html\

Picture 1

Exhaust vent

Picture 2

Heating elements located in basement of school

Picture 3

Duct allowing heated air to rise

Picture 4

Missing mortar

Picture 5

Fissure in foundation

Picture 6

Space between door and frame

Picture 7

Space between doorframe and exterior wall

Picture 8

Damaged window frame

Picture 9

Debris in drainage pit

Picture 10

Plants in classroom

Picture 11

Plant on carpet

Picture 12

Space between sink countertop and backsplash

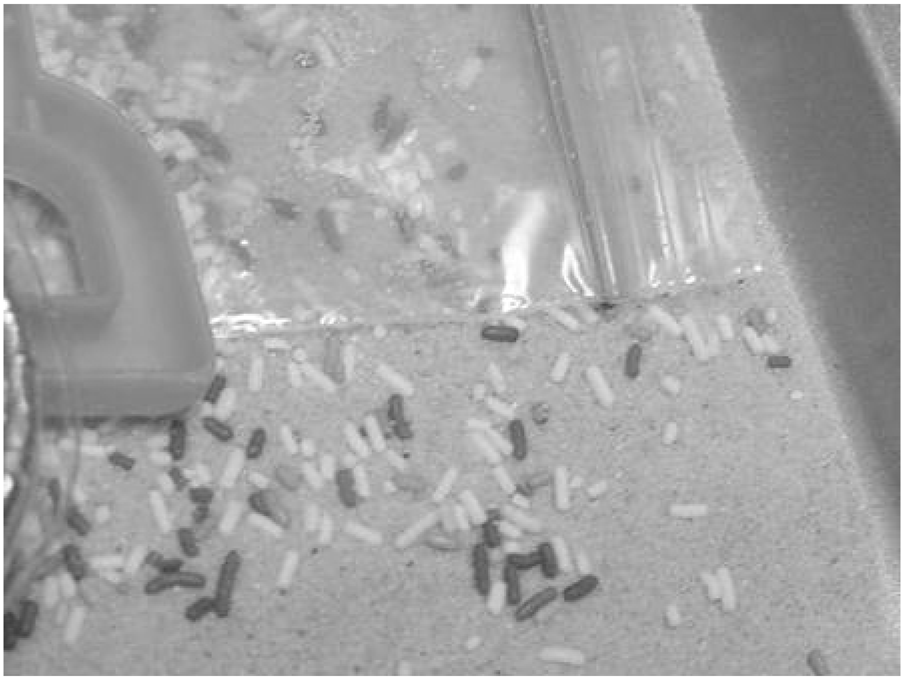
Picture 13

Insect nest

Picture 14

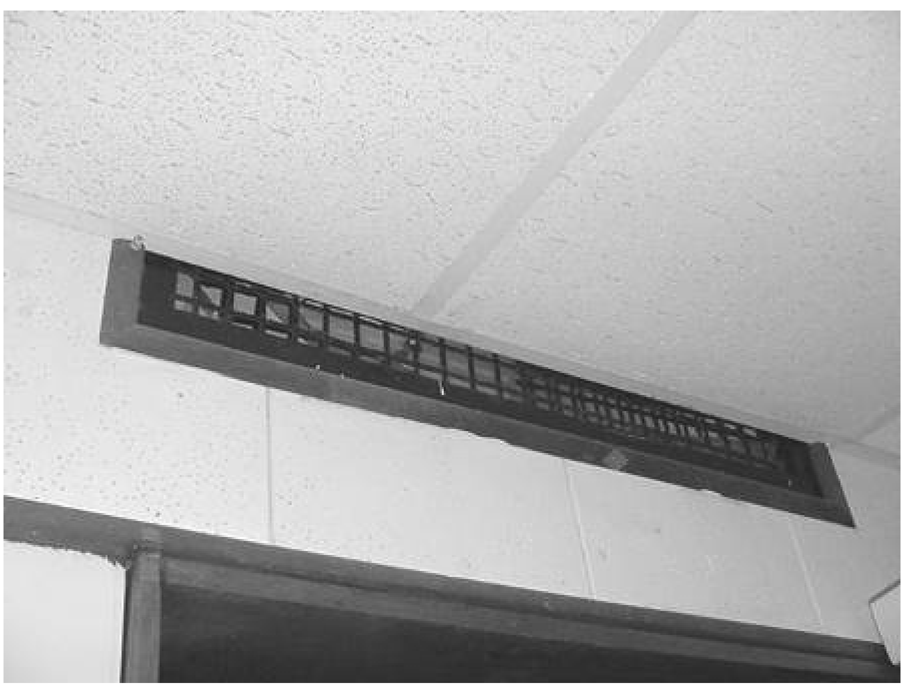
Dehumidifier on carpet

Picture 15



Sugar sprinkles in sand box

Picture 16



Ceiling tile dividing vent

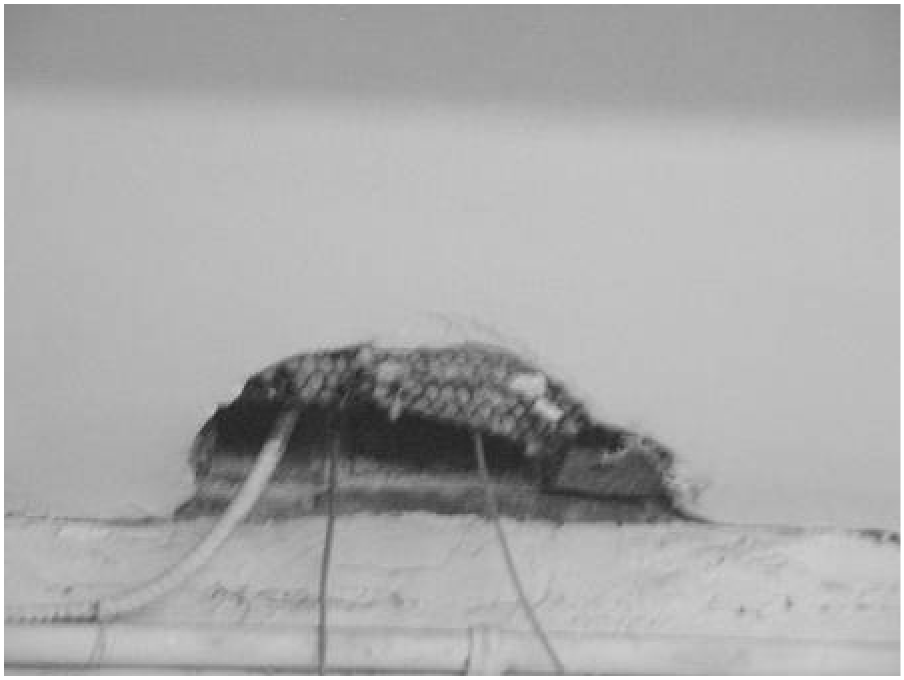
Picture 17

Unsealed abandoned ductwork

Picture 18

Unsealed abandoned ductwork

Picture 19



Breach in wall

Picture 20

Air Purifier

Beal School **Indoor Air Results**

1 Maple Avenue, Shrewsbury, MA 01545 **Table 1** **Date: 03/10/2006**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		54	28	464	ND	ND	76				breezy, overcast; strong mulch odor.
B1 Learning Center	1	74	34	697	ND	ND	18	Y # open: 0 # total: 5	N	N	Hallway DO, DEM, UF, cleaners, dehumidifier, plants, breaches in wall; cleaning agent odor.
B11	0	74	35	820	ND	ND	25	Y # open: 0 # total: 2	N	N	PC.
B14	1	72	39	604	ND	ND	29	Y # open: 1 # total: 3	N	N	Hallway DO, breach sink/counter, DEM, FC re-use, food use/storage, wall breaches/utility holes.
B15 (custodial office)	1	71	43	695	ND	ND	25	N	N	N	Hallway DO, breach in ceiling.
B4	0	74	35	898	ND	ND	22	Y # open: 0 # total: 2	N	N	Hallway DO, cleaners, items hanging from CT.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

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									Supply	Exhaust	
boy's basement bathroom	0	72	37	815	ND	ND	38	N	N	Y wall (off)	
cafeteria	50	74	36	1098	ND	ND	28	N	N	N	
general use room	1	73	33	858	ND	ND	29	Y # open: 0 # total: 2	N	N	
gym	19	72	39	624	ND	ND	29	N	N	N	Hallway DO, Exterior DO, Inter-room DO,
library	1	74	38	798	ND	ND	28	Y # open: 0 # total: 5	N	N	Hallway DO, Inter-room DO,
media/tech side room	0	72	34	627	ND	ND	25	Y # open: 0 # total: 4	N	N	WD-carpet, breach sink/counter, pipe leaks causing WD-carpet; 7 computers.
music	20	73	38	1013	ND	ND	26	N	N	N	Hallway DO, wall breaches.

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OT/PT	0	71	34	582	ND	ND	30	Y # open: 0 # total: 2	N	N	Hallway DO, wall breaches; condensation on pipes; open ductwork.
speech	0	73	32	713	ND	ND	29	Y # open: 0 # total: 2	N	N	Hallway DO,
2	16	72	47	820	ND	ND	33	Y # open: 1 # total: 5	N	Y wall (off)	Hallway DO, breach sink/counter, items.
3	18	72	44	788	ND	ND	43	Y # open: 1 # total: 6	Y wall		Hallway DO, breach sink/counter.
4	17	74	43	878	ND	ND	33	Y # open: 0 # total: 5	N	Y wall (off)	Hallway DO, #MT/AT: 1, DEM, items, plants.
5	16	74	43	755	ND	ND	42	Y # open: 1 # total: 5	N	N	Hallway DO, plant(s) on carpet, PF, aqua/terra, items hanging from CT, plants.
6	0	71	42	453	ND	ND	32	Y # open: 0 # total: 5	N	N	Hallway DO, FC re-use, plants.

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6	20	73	42	624	ND	ND	34	Y # open: 0 # total: 5	N	N	items.
7	0	71	42	551	ND	ND	29	Y # open: 0 # total: 5	N	Y wall (off)	Hallway DO, UF, aqua/terra, cleaners, items hanging from CT, transoms.
7	17	73	42	686	ND	ND	34	Y # open: 0 # total: 4	N	N	plants.
8	20	74	35	1094	ND	ND	27	Y # open: 1 # total: 6	N	Y wall (off)	breach sink/counter, cleaners, FC re-use, items.
9	16	75	34	1038	ND	ND	32	Y # open: 1 # total: 5	N	N	Hallway DO, DEM, cleaners, items.
10	17	73	42	872	ND	ND	38	Y # open: 1 # total: 5	N	N	Hallway DO,
14	16	73	40	678	ND	ND	32	Y # open: 2 # total: 5	N	Y wall (off)	Hallway DO, breach sink/counter, PF.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Beal School **Indoor Air Results**

1 Maple Avenue, Shrewsbury, MA 01545 **Date: 03/10/2006**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
15	17	74	38	597	ND	ND	28	Y # open: 1 # total: 6	N	Y wall (off)	Hallway DO, breach sink/counter, aqua/terra, cleaners, plants, items placed in front of heating elements.
16	15	75	39	663	ND	ND	27	Y # open: 1 # total: 5	N	Y wall (off)	Hallway DO, breach sink/counter, PF, cleaners, pests, items placed in front of heating elements.

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